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DGPS Broadcast Site Performance

The success of the DGPS radiobeacon broadcast service can be credited to the efforts of the U.S. Coast Guard (USCG). The USCG developed this service to provide mariners with reliable position accuracies of better than 10 meters when navigating in harbor and harbor approach areas of continental U.S., Alaska, Hawaii, and Puerto Rico. The service was designed around the proven technology of the radiobeacon transmitter and made use of the existing radiobeacon infrastructure. The service was soon expanded, by the USCG and the U.S. Army Corps of Engineers (COE), to include coverage of the Great Lakes and Mississippi River and other uses such as rescue operations, dredging operations, and hydrographic surveys became common. Although the broadcast site performance factors described below were initially developed for navigation on the waterways,[9] they apply equally well to the nationwide DGPS service, as coverage of the DGPS radiobeacon correction signal is expanded over the country.

4.1 Accuracy

With the full satellite constellation in place the position accuracy of the DGPS service will be within 10 meters (2drms) in all specified coverage areas. The accuracy of the DGPS correction signal depends on precise knowledge of the position of the GPS antennas at each broadcast site. At each of the USCG and COE DGPS radiobeacon broadcast sites, the National Geodetic Survey has installed geodetic monuments referenced to the NAD 83 Coordinate System to provide this position accuracy. Since the DGPS reference station utilizes these monuments, the user's differentially-determined position solution is inherently transformed into the NAD 83 Coordinate System. Geodetic monuments will be required at new DGPS radiobeacon broadcast sites for accurate positioning of the reference station antennas.

A reasonable approximation for determining the achievable accuracy at a given point is to take the typical error at a short baseline from the reference station (on the order of 0.5 meters), add an additional meter of error for each 150 kilometers of separation from the reference station (broadcast site) and add an additional 1.5 meters of error for the user equipment. Some high-end user sets are achieving pseudorange measurement accuracies of less than 30 centimeters for a given pseudorange in the absence or the abatement of multipath. Hence, one can readily see that for the user with high-end equipment who is within 300 kilometers from a given broadcast site, the achievable accuracy is better than 5 meters (2drms). Note that although this higher accuracy is achievable, the present system computes the protection limit for the integrity alarm at 8 meters (2drms).

4.2 Availability

Availability for a given broadcast is defined as the percentage of time in a one-month period during which a DGPS broadcast transmits healthy correction signals at the specified output level. The current DGPS navigation service was designed for, and is operated to, maintain a broadcast availability level which exceeds 99.7%, assuming a complete and healthy satellite constellation is in place.

The most significant availability specification is the availability at the user location which is simply referred to as user availability. It is the most difficult to quantify due to the nature of the atmospheric noise. Quantitative analysis shows that for a given coverage area it lies somewhat higher than 98%, but empirical data with the latest MSK receiver technology need to be collected over a period of several years in order to ascertain a more exact number. In applications where the user availability is required to be high, the user can employ complementary technologies such as map-matching, dead reckoning, or inertial navigation to provide very high availability of position information, even if the DGPS broadcast correction signal is interrupted for short periods.

The phenomena which mainly determine the user availability level of the service in a given coverage area are equipment reliability and broadcast link robustness. The use of redundant equipment is utilized in many aspects of the system and most areas can be covered by redundant broadcast sites, as shown in chapter 5. The signal strength and structure utilized is designed to overcome the time variant levels of atmospheric noise and thus provide the specified level of availability. Since the reference station/integrity monitor sets can operate autonomously without regular intervention from the control center, the communication lines have a reduced effect on system availability. Each broadcast site provides the redundancy of two reference station/integrity monitor sets. Under certain circumstances the switch over between sets will occur automatically and under other circumstances it will require intervention from the control center.

4.3 Integrity

System integrity is built upon the foundation of the integrity monitors. The integrity monitors will ensure the integrity of the broadcast pseudorange corrections and broadcast an alarm message to the user if the corrections fall outside preset limits. The user equipment plays a significant role in assuring that the integrity of the system is preserved. It should be capable of automatically selecting the appropriate radiobeacon from the available broadcast signals.

The function of the integrity monitor that is important to the user is the alarm that is broadcast when any error is detected, and the critical factor in some applications is the time required for the user to receive the alarm message. The time from when an error is detected to when the user equipment is alarmed by the broadcast is less than 4 seconds for 100 bps transmission rates. A complete description of alarm conditions and the alarms broadcast to the user is given in the "Broadcast Standard for the USCG DGPS Navigation Service."[9]